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Success factors in process based mass customization/value engineering projects : a case study

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SUCCESS FACTORS IN PROCESS BASED MASS CUSTOMIZATION / VALUE ENGINEERING PROJECTS – A CASE STUDY

by

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ABSTRACT

Mass Customization (MC) has been a relatively recent phenomenon, introduced in Management circles as a new frontier in business competition for both manufacturing and service industries. Value engineering (VE), on the other hand has been around since as early as World War II, and has established itself as a powerful tool for cost reduction as well as for product and service improvements. The focus of this thesis is to study the success of implementing these two initiatives together, specifically related to their employment at a leading specialty chemical company in Northeastern USA. MC/VE projects are playing an important role in helping this company to lower its costs and shorten delivery times for its diverse system offerings.

What are the parameters of success of an MC/VE project, i.e. what are some of the conditions that foster a positive result in them? More importantly, what are the measures of success of an MC/VE undertaking? What underlying organizational, logistical, and "human" issues does management need to be aware of before applying MC/VE techniques? How can the Company ensure success in future MC/VE efforts? These are some of the questions tackled in this paper. The author has researched these projects as they have been executed in the organization's Electronics Engineering Division. Information related to the MC/VE projects, as employed in the improvement of the design and manufacturability of three of the Division's product lines, has been gathered via surveys, interviews, and company records, in order to try and test the propositions put forward by the author.

The results of this study indicate that the organization's MC/VE projects are indeed successful, as defined by the researcher. The researcher has identified two

possible relationships between successful MC / VE projects and the independent variables as proposed in the thesis. There are some organizational issues that surfaced during the duration of the study, like the need for a more cross-functional product line-oriented departmental structure, and its unwillingness to implement the resultant product configuration software that is the outcome of the MC/VE effort. Finally, the organization may benefit from having a full-time project engineer to track the more complex MC/VE projects.

INTRODUCTION

Background

Company "A" (the name has been withheld for security reasons) is a leading chemical company based in the northeastern part of the USA. It has a diversified portfolio of systems that it manufactures and industries that it services and ranks No. 1 or 2 in most of the industry segments that it is involved in. These markets can be described as oligopolistic, involving a small number of large firms.

The Electronics Division within this company services the semiconductor industry, supplying gases and chemicals, as well as equipment that generates, distributes, purifies, and performs purity monitoring of these gases and chemicals. Compared to other groups within the company, this Division is fairly "young", having been established in 1990, and is regarded as a "maverick" in terms of the non-traditional and speedy way it conducts its business. This is obviously an influence of the industry that it serves, where innovation cycles run in months rather than years! The prevailing thought-process within the Division (until very recently) was that the gas or chemical supply contracts (which are quoted in tens of years) make up the bulk of the revenue and profits; "we do not make money on equipment, we just have to break even on it". As a result, the equipment systems have to be relatively cost conscious, extremely reliable (so as not to interrupt flow of gas or chemical to the customer), and be easily maintainable. Often, the customer dictated what features these systems should have.

Between 1990 and 1995, the equipment design and manufacture within the Engineering Department was undertaken as an "Engineered to order" project. Each successive system was treated as a unique project unto itself, with the design partly copied from previous projects, and “minor” changes added to conform to the specifications of the new customer. This resulted in unnecessary features, parts and options being “lumped” into the equipment in successive iterations, thereby increasing cost and time needed to manufacture it.

In 1995, the Commercial / Marketing / Sales group within the Division approached the Engineering Department to find ways to cut costs and manufacturing lead times for one of its product lines (henceforth called “Product Line GG” in this thesis). In answer, a massive project was undertaken to completely overhaul the design and manufacturing aspects of this product line. The technique used was a combination of processes and design tools called Mass Customization (MC) and Value Engineering (VE). Since then, this approach has also been successfully used to re-define two more product lines (hereafter called “Product Line B” and “Product Line QC”).

The MC / VE process enabled the organization to re-define the product lines into “engineered systems” used in gas and chemical distribution. The concept was simple: establish a common “platform” or “system” base design, which contains all of the *required* functionality for that particular product line. Then, allow the design to be flexible enough to include 80% of “optional” features routinely requested by the organization’s customers. This is to be engineered in such a way as to be able to pick and choose the relevant options without disturbing the base design, and create unique “products” for the unique customers. The complete process would be supported right from the commercial / sales / marketing department, to the engineering group, to the manufacturing arm of the organization.

Definitions

(1) **Mass Customization**: "The *mass* production and distribution of individually *customized* goods and services". (Joseph Pine, 1992)[1].

As a technological capability, mass customization was anticipated in 1970 by Alvin Toffler in *Future Shock*[2] and named in 1987 by Stan Davis in *Future Perfect*[3]. Joseph Pine in 1992 wrote a series of articles, culminating in a book called *Mass Customization*, where he set down rough guidelines on how to approach mass customization of products and services. Since then, numerous articles have appeared in leading management journals (Harvard Business Review, Strategic Management Journal, etc.), as well as in popular magazines (Fortune, Forbes, business Week, etc.), which have broadened the boundaries of this subject.

Mass Customization is a synthesis of two competing systems of management – mass production and craft production. Like craft production, mass customization has a high degree of flexibility in its processes, uses general-purpose tools and machines as well as the skills of its workers. It builds to order rather than to plan, and it results in high levels of variety and customization in its products and services. Like mass production, it generally produces in high volume, has low unit costs and often (but not always) relies on a high degree of automation. By combining elements of mass production, with elements that allow for a high degree of design flexibility, mass customization captures the strengths and benefits of both mass and craft production. It creates a more cost-effective, flexible, and near custom-fit product.

In mass customization, low costs are achieved primarily by utilizing economies of scope (the application of a single process to produce a greater variety of products and services cheaply and quickly) as well as economies of scale (a greater output and faster throughput of the production process). This as opposed to mass production, which achieves low costs only through economics of scale. Four basic innovations together achieve both "mass" and "customization":

- Just-in-time delivery and processing of materials and components that eliminate process flaws and reduce inventory carrying costs.
- Reducing setup and changeover times, which directly lowers run size and the cost of variety.
- Compressing cycle times throughout all processes in the value chain (which eliminates waste) to increase flexibility and responsiveness while decreasing costs.
- Producing upon receipt of an order instead of a forecast, which lowers inventory costs, eliminates write-offs, and provides the information necessary for individual customization.

(2) **Value Engineering**: "A systematic effort directed at analyzing the functional requirement of a system / equipment / facility / supply, for the purpose of achieving essential functions at the lowest total cost, consistent with the needed performance, reliability, quality, and maintainability". (Armed Forces Definition)[4].

The origins of value engineering[5] trace back to the General Electric Company (GE) around World War II, where studies were being done of product changes resulting from material shortages. The purchasing people at the company had the challenge of substituting materials without sacrificing quality and performance, on several hundred of GE's products. Larry Miles, then director of purchasing at GE's Schenectady, NY plant, was surprised to find that these changes had produced substantial product improvement and cost reduction. The substitution of new materials and manufacturing technology in older designs had resulted in fewer parts, lower costs, and higher quality in the resultant products when compared to their predecessors. Miles developed a formal methodology, called *Value Analysis,* in which teams of people reexamined the design of products manufactured by GE. This technique was adopted by many other organizations, including the Navy Bureau of Ships[6] in 1954. The program was retitled "Value Engineering" (VE) to reflect the engineering emphasis of the Bureau of Ships.

Today VE refers to a process that an interdisciplinary design team trained in value analysis uses to design a new product, process, procedure, or service. These teams:

- Analyze components and the functions they perform.
- Gather and interpret cost data.
- Measure value in terms of functions that fulfill customer needs, goals, or objectives.
- Develop and evaluate alternatives to improve or eliminate low value adding components.
- Develop ways to implement the best alternative.

Value studies make use of a structured approach that Larry Miles referred to as a *job plan*. There are six phases in the job plan:

- Origination phase: Project and personnel selection.
- Information phase: component, cost, and desired performance information.
- Analysis phase: functional and cost analysis.
- Value measurement: via subjective or formal value measurement techniques.
- Innovation phase: generation of design alternatives.
- Evaluation phase: Decision on best alternative via cost and technical analysis.

Throughout each of the first 5 phases of the job plan, detailed answers are sought to five questions developed by Miles that must be answered before an improvement can be made. They are:

- What is it?
- What does it do?
- What does it cost?
- What is it worth?
- What else will do the job?

LITERATURE REVIEW

The author researched the existing literature on the Behavioral, Organizational, and Procedural aspects relating to success in Mass Customization and Value Engineering projects.

<u>On Mass Customization</u>

Joseph Pine's book is widely regarded as a bible for anyone who wants to make the shift towards Mass Customization. He has devotes a couple of chapters on what works and what doesn't work regarding successfully implementing Mass Customization projects within an organization. As he puts it, "A large part of ...(succeeding through Mass Customization methodology)...*involves searching for the requirements of individual customers*: current customers whose requirements will change over time as well as new customers whose needs have yet to be met or ascertained". This means that the accuracy of market information gathered is critical to ensuring success. Other steps towards sustaining this success, according to Pine, include:

- *The gaining of knowledge of the shift to Mass Customization and the desire to change*. One has to understand that the present process is not working in an increasingly turbulent world and that moving to Mass Customization is essential for long-term business survival. Hand in hand with this is the requirement for a desire to change. In many cases, this may arise from the occurrence of a crisis within the organization. Both the upper management as well as the employees within the organization share this responsibility and must show that they have "bought in" into the Mass Customization philosophy.
- *The creation of a vision* – to determine and communicate where you want to go. Top management must make it clear to all that change is necessary, and then point out the direction and magnitude of the required change.
- *The development of a strategy on how to proceed and the execution of that strategy*. This strategy should connect where the firm (or product) currently stands and its desire to change with where it should be, by laying out the first stepping-stones along the journey. Strategies should be robust and capable of addressing rapid environmental changes without waiting for a new strategic cycle. Great care must be taken that Mass Customization does not come across as a fad or program of the month. Further, the steps within Mass Customization projects can be solidified into Organizational Work Processes or procedures that will ensure a standardized metholodogy for these projects to follow.

Along with the above changes, the organization itself must be transformed into an integrated unit in which every function, unit, and person is focussed on the individual customer. Each does *whatever is necessary to develop, produce, market, and deliver low-cost, customized products and services.* Management must concentrate not only on *what* the organization must do but even more important on *how* the organization can accomplish this goal. Gearing for success will also require creating and empowering cross-functional teams that can quickly bring together the diverse skills, knowledge, and experience needed to accomplish the task on hand. As an outcome of Mass Customization, consolidation of the organization's value chains also occurs, which also facilitates speed to market. Finally, for those that make the transition to Mass Customization, it must be realized that the turbulence in the marketplace will not end, but they will once again have their hands at the controls.

David Anderson[8], in his book on Mass Customization, says that the first step in any product development is to translate the *voice of the customer into product design specifications* and *resource prioritizations.* The proper procedure for an intriguing concept or technological strength would be to first *investigate the market potential.* Further, through the project, it is important to *raise and resolve issues* as soon as they are identified (technical or otherwise). Starting with a *multifunctional team* has the advantage of offering a variety of opinions that are available from people with diverse backgrounds, education, and experience. Finally, according to him, most mass customized products will have too many possible configurations and too many rules to keep track of on paper. The relationships between configurations and rules may be too complicated to easily set up on a spreadsheet and database. Fortunately, today, *Configuration software*, called "configurators" has been developed to keep track of all the options and features and all the rules that apply to their use. These expert systems have configuration engines that can do the relevant calculations in the background, and can present the customer or the sales force with the tools to request a "customized" order.

On Value Engineering

The book by Shillito and De Marle bring out some interesting viewpoints as to what factors contribute towards a successful Value Engineering (VE) venture. They discuss the John Warfield Model[7] (called "the fundamental triangle of societal problem solving"), in which there are 3 basic interdependent elements to addressing an issue: the issue itself, an interdisciplinary team, and an appropriate methodology (shown below in Figure 1). The interconnections of these elements involve people, teams, organizations, and politics, which further compound the relationships. If a flexible, simplistic methodology (like VE) can be developed that can serve both the team and the issues, then there is a greater chance of connecting the team successfully with the issue. *The more multidisciplinary the VE team, the better the connection.*

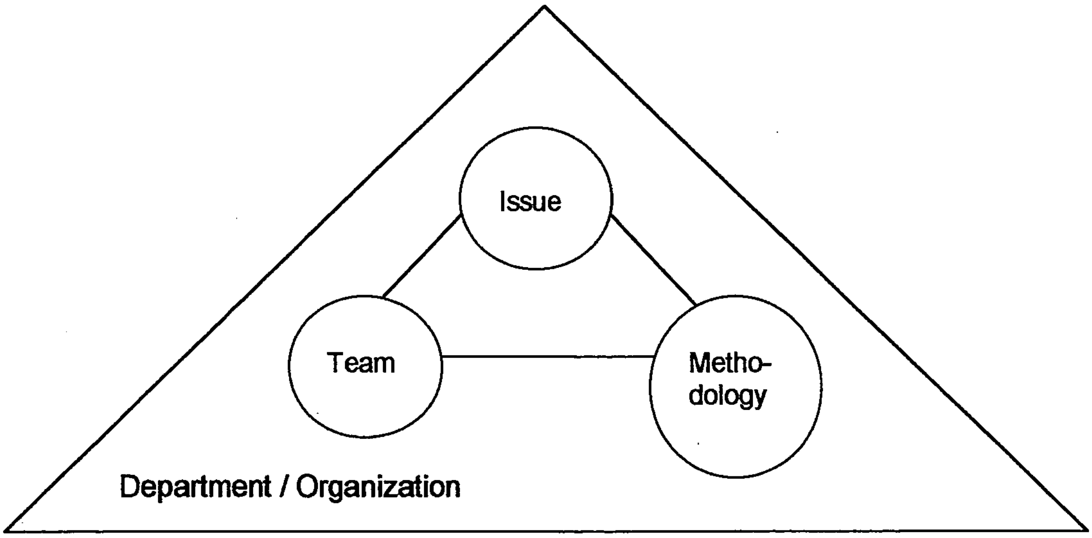

Figure 1: Organizational model of an issue.

The successful application of value engineering projects and methodology is very often weakened, because the behavioral, people, political, and organizational elements are not addressed properly. Although the value engineering process is systematic and structured, its foundation is structured around the effective use of people in teams and subsequently their interaction with the management chain in making recommendations that ultimately will lead to implementation and change.

When starting a VE project, the following issues must be thoroughly addressed:

- *Purpose*: Why are we doing this VE project? Purpose / Mission Statement generation.
- *Alignment*: Who is the decision-maker? Who pays the implementation costs? Who does the team report its results to?
- *Scope*: What is included / not included in the study? What are the boundaries within which the team operates?
- *Time horizon*: What is the introduction or implementation year for the product under study?
- *Completion date*: When is the VE project to be completed by?
- *Market*: What are the market, segment, and customer influences?
- *Selection of Study team members*: Are the right people in the core team? Who facilitates? Are ad-hoc members needed? Steering team members? Team leader selection is critical.
- *Assumptions*: Are they well documented?
- *Company business plan*: What is it? Is it available to the VE team?

- *Implementation*: What needs to happen before the result can be implemented? What will come in the way of implementation and how are they to be resolved?
- *Project selection*: Any project selection criteria to be followed? Sacred cow project?

The discussion and documentation of the above topics are integral to the success of the VE project. A poor job here can cause teams to be off course, lose time, and develop excellent recommendations on the wrong thing. The success of the VE project is enhanced if organizational, political, and behavioral aspects of the project are addressed early in the project. Roadblocks can be anticipated and planned for before they occur. Some common stumbling blocks encountered in the VE process are:

- Teams can waste time, be overly conservative, avoid decisions, and prematurely solve unclear problems.
- Individuals involved in the VE teams usually have other full-time jobs and are already busy.
- Strong parochial interests are common.
- The output of the VE exercise may be threatening, especially to designers, planners, and decision-makers.
- The purpose of the VE project is not always clear.
- The final decision-maker is not always obvious.
- Lack of management support. Lip service. Priority re-allocation mid-stream. This results in people spending their time on the more "visible" projects.

Sometimes the VE process is considered a hindrance to meeting the overall deadline for getting a product to market. A haphazardly conducted VE project is more harmful to the organization than not doing one at all.

PROBLEM STATEMENT

Presently, both the management and the employees within the Electronics Division of the organization under study have completely embraced the MC / VE philosophy as a means of tackling cost and lead time reduction and design improvisation within the various product lines. But, the following questions need to be answered before embarking on another one of these projects:

(1) Have these projects been truly successful?

(2) How do we define success in these projects?

(3) What internal and external circumstances determine whether these projects succeed or fail?

The Division is at a point where, after four years of implementing MC / VE projects (on three product lines), it has sufficient raw data on the effectiveness of this technique. Appendix 4 has the details on the MC / VE process as it is employed at the company under study[12]. This paper tries to identify those underlying parameters and characteristics (organizational, procedural, "human", etc.) which dictate the degree of success within these MC / VE projects. The results of these three MC / VE projects are compared and contrasted. The author puts forward certain propositions relating to what internal and external influences have to be controlled or taken care of, so as to achieve optimal results in these projects. These can be broadly grouped under the following categories:

(1) Management commitment

(2) Project team leadership

(3) Market conditions

(4) Supporting documentation and information technology

(5) Degree / amount of Mass Customization performed

(6) Degree / amount of Value Engineering performed

(7) Customer influence (external / internal)

(8) Adherence to Work Processes / Procedures defined for Project execution of this type

RESEARCH OBJECTIVES

Each of the eight categories mentioned above can be re-worded in terms of a Proposition to be tested. Table 1 below lists those propositions:

TABLE 1: PARAMETERS CONTRIBUTING TO THE SUCCESS/FAILURE OF A MASS CUSTOMIZATION / VALUE ENGINEERING PROJECT

(1) Management Commitment
(1a) The greater the top-down Management Commitment / push, the greater the chances of success.
(1b) The greater the amount of departmental resources devoted to the project, the greater the chances of success.
(1c) The lower the turnover within the project teams, the greater the chances of success.
(1d) The clearer the project definition from management, the greater the chances of success.
(2) Project Team Leadership
(2a) The fewer the changes in project leadership, the greater the chances of success.
(2b) The greater the drive to complete the project work (especially at the end of the project), the greater the chances of success.
(2c) The greater the consensus on technical issues in the project, the greater the chances of success.
(3) Market Conditions
(3a) The greater the maturity of the product line in the market place, the greater the chances of success.
(3b) The more accurate the market information (commercial input, identification of the correct options), the greater the chances of success.
(3c) The higher the product volumes, the greater the chances of success.
(4) Supporting Documentation / Information Technology
(4a) The greater the generation of position papers, work instructions, etc., the greater the chances of success.
(4b) The greater the amount of information technology used (e.g., configurator programs), the greater the chances of success.
(5) Amount of Value Engineering Performed
(5a) The greater the degree of Value Engineering performed, the greater the chances of success.
(6) Amount of Mass Customization Performed
(6a) The greater the degree of Mass Customization performed, the greater the chances of success.
(7) Customer Influence (external / internal)
(7a) The greater / lesser the amount of customer influence, the greater the chances of success.
(8) Adherence to Work Process for Project Execution
(8a) The greater the adherence to the Work Process laid out for these projects, the greater the chances of success.

All of the above categories have been chosen by the researcher, based on his personal experiences with these types of projects, as well as information gleaned from the available literature on the subject (described in the Literature Review section above).

In order to answer the question as to what parameters contribute to a successful MC / VE project, the researcher first had to define the criteria for judging how successful a given project was. What are the indicators of success in these projects? To answer that question, the researcher decided on 6 "Key Performance Indicators" which could be used to judge the results of the project. They are:

(1) Unit Cost Reduction on the system.

(2) Reduced Time to Market.

(3) Improved Quality (related to documentation, manufacturing defects, work processes, operability, reliability and performance of the system).

(4) Project completion within the specified Budget.

(5) Project completion within the specified Timeframe.

(6) Amount of recurring engineering still being performed on the Mass Customized / Value Engineered system.

METHOLODOGY AND DATA COLLECTION

Grounded theory, along with qualitative research methods, was used to identify, sort, and study key MC / VE related data and experiences occurring within the Engineering Department of the Division. Grounded theory, as defined by Strauss and Corbin[9], "....is one that is inductively derived from the study of the phenomenon it represents....One does not begin with a theory, then prove it. Rather, one begins with an area of study and what is relevant to that area is allowed to emerge." Another way

Grounded Theory can be explained is as follows: "...to watch and record, not with the intention to confirm or disconfirm, but rather with the intention to 'see'..." (Gersick, 1988)[10] .

A well-constructed grounded theory meets 4 central criteria for judging the applicability of theory to a phenomenon: fit, understanding, generality, and control[11]. Hence, it was an ideal tool in deciphering the data collected by the researcher on the subject.

The qualitative research method relies heavily on surveys, interviews, focus groups, archival data, and other techniques to gather information on the phenomenon being studied. Here, quality research was used to uncover the opinions and capture the attitudes of some of the employees within the Department towards MC / VE projects.

The researcher was a participant member of 2 of the 3 MC / VE projects being studied, which provided him the advantage of ready access to the organization, its individuals and archival data. The study was conducted with full approval of upper management. To ensure anonymity and company confidentiality, no information (such as employee names) has been provided, nor has any reference been made here to the Company's name, its product and product line names.

The primary vehicle for data collection was a survey (as included in Appendix 1 and 2). The survey gathered data on both the measures of success as well as the independent variables potentially contributing to the success of these projects. 9 employees, who were either directly or indirectly involved with one or more of the 3 MC /

VE projects under study, were asked to fill out the survey questionnaire. This included the researcher as well as individuals from management. The participants were asked to rate (in their opinion) how well or badly each measure and variable fared, when executing that project. The rating system used numbers between 1 and 6, 1 being low and 6 being high in ascending order. So as to receive consistency in interpretation within the rating system, the researcher pre-defined what would constitute a low, a medium or a high response within each category.

Once the survey had been filled out, the researcher interviewed each participant on the evaluations. The interviews were unstructured, focussing mainly on getting feedback as to why the employees responded to the categories as they did. That is, what were the circumstances surrounding their experience that made category X a "low 2" or a "high 6" in their judgement? The questions asked by the researcher in these interviews were open-ended, to allow for views and opinions to come through. The interviewing process was kept private, conducted face-to-face, with a time frame of about 10 to 15 minutes each. The resultant data was open-coded (Strauss and Corbin, 1990) using constant comparative analysis, i.e., information from past interviews was fed back in later interviews. Initial findings were shared with the interviewees for corroboration of data and to ensure that the findings were in tune with their attitudes and views. A "first order" analysis of the data has been included here, i.e., a description of "what is going on".

Data validation was also carried out with the help of a "key informant", the Manager of Product Supply Team (PST) Engineering, who has been instrumental in the introduction, strategy development, and planning for the MC / VE project implementation within the Department. This person served as an information giver, as well as an information validator, guiding this researcher through the study.

Further data gathering was facilitated via the data compiled from the personal observations of the researcher. These observations primarily took place while attending team meetings during these projects. There, the researcher got first-hand knowledge of the inner workings and procedures involved in the execution of these projects. Additional information was also collected via personal interaction between the researcher and other team members outside of these meetings.

Finally, there was the use of archival data – internal company documentation, mainly in the form of Work Instructions as well as memos from upper management as well as between the core team members, written over the course of the last 4 years. This information led credence to and corroborated any conclusions that the researcher arrived at. Thus, the triangulation test for validation of the findings was followed via interviews and surveys, personal observation and corroboration via the key informant, and archival and historical data.

DATA ANALYSIS

Tables 2 and 3 below summarize the results from the survey questionnaire distributed to those in the organization who were directly involved with the 3 MC / VE projects under study. As explained before, the respondents were asked to rate each category using numbers between 1 and 6, with 1 being a low rating and 6 being the highest rating for that category. The data has been purposely kept in its "raw" format, since any averaging or statistical analysis would be misleading, due to the major deviations in responses and the small number of survey respondents.

TABLE 2: MEASURES OF SUCCESS IN A MASS CUSTOMIZATION / VALUE ENGINEERING PROJECT (SURVEY RESPONSES)

Product Line "B" respondents (R1 to R6)	R1	R2	R3	R4	R5	R6	Total
(1) Unit Cost Reduction on the product.	6	6	4	6	6	4	32
(2) Reduced Time to Market.	5	4	4	4	3	5	25
(3) Improved Product Quality (related to documentation, manufacturing defects, work processes, operability, reliability and performance of product).	4	4	4	6	4	1	23
(4) Project completion within the specified Timeframe.	3	4	4	5	4	4	24
(5) Project completion within the specified Budget.	3	4	4	5	4	4	24
(6) Amount of recurring engineering still being performed on the Mass Customized / Value Engineered product.	3	2	3	3	1	4	16
TOTAL							**144**

Product Line "GG" respondents (R1 to R6)	R1	R2	R3	R4	R5	R6	Total
(1) Unit Cost Reduction on the product.	5	4	6	6	4	4	29
(2) Reduced Time to Market.	5	3	6	4	4	5	27
(3) Improved Product Quality (related to documentation, manufacturing defects, work processes, operability, reliability and performance of product).	5	4	6	4	5	1	26
(4) Project completion within the specified Timeframe. (* = 2 numbers were returned, one for the Mechanical design M and the other for the Controller design C)	5M 2C *	2	6	4	1	4	22 or 19
(5) Project completion within the specified Budget.	4M 2C *	4	4	4	1	4	21 or 19
(6) Amount of recurring engineering still being performed on the Mass Customized / Value Engineered product.	6	4	5	1	4	5	25
TOTAL							**150 or 145**

Product Line "QC" respondents (R1 to R6)	R1	R2	R3	R4	R5	R6	Total
(1) Unit Cost Reduction on the product.	5	5	3	6	6	5	30
(2) Reduced Time to Market.	5	4	3	6	4	3	25
(3) Improved Product Quality (related to documentation, manufacturing defects, work processes, operability, reliability and performance of product).	5	3	5	5	4	3	25
(4) Project completion within the specified Timeframe.	5	3	4	5	4	4	25
(5) Project completion within the specified Budget.	5	5	6	5	4	5	30
(6) Amount of recurring engineering still being performed on the Mass Customized / Value Engineered product.	6	6	6	4	6	6	34
TOTAL							**169**

TABLE 3a: PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF A MASS CUSTOMIZATION/VALUE ENGINEERING PROJECT (SURVEY RESPONSES)

Product Line "B" respondents (R1 through R5)	R1	R2	R3	R4	R5	R6	Total
(1a) Top-down Management Commitment / Push. (* = 2 numbers were returned, one for the Mechanical design M and the other for the Controller design C)	3	4M 2C *	5	6	3	4	25 or 23
(1b) Departmental Resources devoted to Project.	3	5M 2C	5	4	4	5	26 or 23
(1c) Continuity of members within Project team.	4	6	1	6	6	6	29
(1d) Clarity of Project Definition	4	3M 1C	6	5	3	4	25 or 23
(2a) Project Leader, Facilitator (constancy, quality).	4	4	5	6	4	4	27
(2b) Drive to Project completion.	4	5	2	3	3	3	20
(2c) Consensus on technical issues within Team.	5	3M 4C	3	4	4	4	23 or 24
(3a) Degree of Product maturity in marketplace.	3	6	3	5	3	5	25
(3b) Accuracy of market information, identification of correct options.	3	4M 2C	4	2	4	2	19 or 17
(3c) Product volumes.	4	4	4	4	4	4	24
(4) Supporting Documentation / Information technology.	4	2	4	3	2	3	18
(5) Amount of Value Engineering performed.	5	5	3	4	3	5	25
(6) Amount of Mass Customization performed.	4	4	4	6	4	4	26
(7) Customer Influence (external / internal).	4	3	5	2	4	3	21
(8) Adherence to Work Processes.	4	3	4	5	4	4	24

TABLE 3b: PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF A MASS CUSTOMIZATION/VALUE ENGINEERING PROJECT (SURVEY RESPONSES)

Product Line "GG" respondents (R1 to R6)	R1	R2	R3	R4	R5	R6	Total
(1a) Top-down Management Commitment/ Push.	6	3	6	6	6	3	30
(1b) Departmental Resources devoted to Project.	6	3	6	4	5	2	26
(1c) Continuity of members within Project team.	6	2	5	6	6	3	28
(1d) Clarity of Project Definition	6	4	6	5	5	4	30
(2a) Project Leader, Facilitator (constancy, quality).	6	4	5	6	5	1	27
(2b) Drive to Project completion. (* = 2 numbers were returned, one for the Mechanical design M and the other for the controller design C)	6M 4C	2	6	3	3	4	24 or 22
(2c) Consensus on technical issues within Team.	6M 4C	4	2	4	4	5	25 or 23
(3a) Degree of Product maturity in marketplace.	6	6	6	6	6	6	36
(3b) Accuracy of market information, identification of correct options.	6	4	6	5	6	5	32
(3c) Product volumes.	6	6	6	6	6	6	36
(4) Supporting Documentation / Information technology.	6	4	6	6	4	4	30
(5) Amount of Value Engineering performed.	6	2	4	6	5	6	29
(6) Amount of Mass Customization performed.	6	5	5	4	6	6	32
(7) Customer Influence (external / internal).	4	5	6	4	5	6	30
(8) Adherence to Work Processes.	6	4	5	5	3	4	27

TABLE 3c: PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF A MASS CUSTOMIZATION/VALUE ENGINEERING PROJECT (SURVEY RESPONSES)

Product Line "QC" respondents (R1 to R6)	R1	R2	R3	R4	R5	R6	Total
(1a) Top-down Management Commitment/ Push.	3	5	3	2	6	3	22
(1b) Departmental Resources devoted to Project.	5	5	5	4	4	5	28
(1c) Continuity of members within Project team.	5	6	5	2	6	5	31
(1d) Clarity of Project Definition	6	4	6	5	5	5	31
(2a) Project Leader, Facilitator (constancy, quality).	5	6	5	6	6	6	34
(2b) Drive to Project completion.	5	4	4	5	3	5	26
(2c) Consensus on technical issues within Team.	6	5	6	5	4	5	31
(3a) Degree of Product maturity in marketplace.	2	6	6	5	4	4	27
(3b) Accuracy of market info., identification of correct options.	6	5	6	3	5	5	30
(3c) Product volumes.	2	2	2	2	3	2	13
(4) Supporting Documentation / Information technology.	4	4	5	4	5	4	26
(5) Amount of Value Engineering performed.	5	4	4	4	6	4	27
(6) Amount of Mass Customization performed.	4	6	5	5	6	5	31
(7) Customer Influence (external / internal).	4	2	5	4	4	4	23
(8) Adherence to Work Processes.	5	4	6	4	5	5	29

FINDINGS

Looking at the above data and performing the "eyeball" test, all 3 of the MC / VE projects have been successful for the most part, as quantified by the "Measures of success" laid down by the researcher. Overall, Product Line QC received the highest scores, thus making it the most successful MC / VE effort out of the three.

Regarding the "*Measures of Success*" categories:

- All of the product lines had impressive scores for Unit cost reduction (a fact that is validated by company records shown in Appendix 4) and fair scores for reduced time to market, as well as in Improved system quality.

- Product line GG scored low in the categories of Project completion within specified timeframe and specified budget, especially in its controls / electrical design.
- Product line B scored the lowest in the category of Amount of recurring engineering, while Product line QC scored the highest.

Regarding the "*Parameters contributing to Success*" categories:

- Product line B scored low in the category of Accuracy of market information. In contrast, both Product line GG as well as Product line QC scored high in this category.
- Product line GG scored the highest in the category of Supporting documentation / Information technology, whereas Product line B scored the lowest.
- Product Line QC scored the highest in the Project Leader / Facilitator category.

Thus, there seems to be two possible relationships. One may be between the amount of recurring engineering and the accuracy of market information, as well as the Supporting documentation that comes out of the MC / VE efforts. The other may be between the MC / VE project being completed on time and on budget, and the Project Leader / Facilitator constancy and quality.

INTERPRETATION

As described earlier, the survey questionnaire was used by the researcher more as a vehicle to try and gain an understanding about what actually went on in these MC / VE projects, and why the respondents answered the way they did. In these post-survey interviews, the researcher learnt a lot more about the underlying organizational and management issues related to these projects.

- There is a strong deviation between the mechanical and the electrical / controls groups of the organization, with regard to the understanding of the success of the MC / VE projects. In both the Product line B and GG projects, the researcher noticed that the mechanical / piping group on average rated each survey category higher than the electrical / controls group. Therefore the controls group is not as satisfied with the results of the MC / VE effort as the mechanical group. Some of the reasons given were:

  (a) Not enough time was allocated to proceed with the electrical portion of the project.

  (b) There were hardware constraints enforced on the electrical team, which created a "limited" system configuration right from the beginning from their point of view.

  (c) Management involvement in the projects declined once the mechanical portion of the design was completed.

  (d) Non-sufficient resources committed during the electrical design.

In short, there is a general disassociation of the controls group from the rest of the "success" of the MC / VE project. The point of view of the controls group regarding the MC / VE projects is that it does not get the recognition it deserves. Interestingly enough, the researcher did not find any such issue related to the most "successful" MC / VE project (as per the survey results), the QC Product Line. In the researcher's opinion, this may be due to the fact that, during the MC / VE effort for this product line, the controls group was involved up-front, and that the mechanical / piping and the electrical / controls issues were debated simultaneously. Also, the controls group had a free reign in deciding the optimal control platform to be used for the product line.

- The scores under the *Top-down Management Commitment / Push* category were probably affected by other factors (such as the one explained above).
- A very "formal" and defined process of Mass Customization exists within the organization. However, no such detailed definition is present for the Value Engineering portion of the project. The GG product line was the first MC / VE project to be tackled in the organization. In essence, it served as more of a "pilot" project rather than a formal MC / VE project. A lot of the "lessons learnt" were passed down to the other 2 projects, and there was a lot of "process learning" and process formalization that went on during that MC / VE effort. The subsequent projects took advantage of that learning so that some of the mistakes were not repeated, as well as there was a "project blueprint" that could now be followed. For example, the GG Product Line MC / VE Team took almost a full year in preparing a "Functional Requirements" document for its controller design, and only after it was completed did the actual implementation started to occur. Instead, the other product line teams simultaneously worked on both the design as well as the documentation, continuously revising the functional requirements as required, while the MC / VE process progressed. Another example of a modification of the MC / VE effort for the B and QC Product Lines was the enhanced emphasis on the generation of a very specific Mission Statement (that included goals such as "reduce costs by 30%", etc., rather than "design a cheaper system"). This was often revisited during the MC / VE exercises to keep the team focussed on what the real challenges were.
- The most successful MC / VE project was the one involving the QC product line. However, one should note that this product is the "simpler" of the 3 product lines, with the other 2 designs having greater complexity and scope than the QC system. In essence, one may not be comparing apples to apples when talking about the 3

product lines in the same context. Complexity of product or system may be the reason for the discrepancy in the individual survey responses.

- The Product line B received the lowest score in the category of recurring engineering. However, one must understand that this is the most complex "system" of the three, composed of many sub-systems. Thus, its options, with all of the permutations and combinations, are more varied as compared to the other product lines.
- In the case of the GG product line MC / VE project, there was an issue about the number of people devoted to the controls design as well as their skill sets. Further, the project leader for this portion of the project kept changing as time progressed. Also, the people committed for this project constantly had other non-related projects that they were involved with, thus reducing their effectiveness. They were inherently left on their own, without a schedule and task list breakdown. Finally, the controls group took about a year or more to complete the "Functional" specification document, which delayed the project as well. All this led to low scores in the *Departmental Resources devoted to the Project* category!
- In the case of the QC Product Line MC / VE, there was a lack of a clear timetable of when the project should be completed. However, the QC Product Line engineer was the driving force in getting to completion on the MC / VE effort.
- None of the 3 product lines presently uses the configurator programs for system definition. This means that the organization is not reaping the full benefits of the MC / VE process. In this age of E-commerce, having the ability to configure a system online (on the company intranet, involving the commercial / marketing / sales departments along with the engineering and manufacturing groups) would go a long way in the reduction of the costly hand-offs and paperwork that is otherwise required.

Depending on how well this tool gets developed within the organization, there is also the potential of the customer "dialing" into the company web site. A menu and option driven process would enable the customer to obtain cost and lead time information for a "configured" system, which would decrease the number of unwanted and repetitive "back and forth" iterative activities between the sales force and the customer.

CONCLUSION

So what does all this mean?! In the initial stages of this thesis effort, the researcher was trying to compare and contrast the 3 MC / VE efforts so as to try and isolate those traits that make one project more successful than another. However, as the research progressed, the data gathered did not lend itself well in making this comparison. The researcher found two potential relationships, though:

(1) The amount of recurring engineering is directly proportional to the *accuracy of market / commercial information* and the *supporting documentation* resulting from the MC / VE efforts.

(2) The success of the MC / VE project as measured by its being on time and on budget is directly proportional to the *project leadership / facilitatorship*, in terms of its constancy and quality.

As regards the rest of the original eight independent variables described earlier in the problem statement:

- *Customer influence*, external or internal did not seem to play much of a part in the success of the MC / VE projects. The relevant data (such as the "options list") was primarily gathered from the commercial / marketing / sales group, and from within the functional groups within the organization. However, in this respect, the variables like *The Degree of Product Maturity* and *Product Volumes* become important factors in the gaining of the pertinent historical knowledge of what the customer functionally requires the MC / VE system to do.

- *The Project Leader / Facilitator* plays an important role in ensuring that there is *consensus on technical issues* within the team, as well as there is a strong *drive toward project completion.*
- *The Top-down Management Commitment /Push* is vital to the success of MC / VE efforts. Without that, the project would not become a reality, the *appropriate resources* may not become available, and *continuity of the project team members* may get affected. Besides, the all-important "funding" issue is obviously controlled by management!

Above and beyond the success factors as laid down in this thesis, there is also a slew of "lessons learnt" that the researcher unearthed, which can be shared with the organization so as to make future MC / VE efforts more successful:

- Management has a tough task of tackling the controls group's disassociation from the rest of the MC / VE success. The organization still has an intact "functional" sub-division, which leads to too many hand-offs between groups. This creates gaps in the work process, resulting in the MC / VE process breakdown. At the same time the controls group ought to look at the complete picture in terms of success of the overall project, and not just concentrate just on what went wrong in the electrical portion of the project. The controls team is comparing success not to the outcome as in the measures (cost reduction, reduced time to market, etc.) but what could have been accomplished had it been given more opportunity to improve the system.

One of the ways this issue could be handled is to have a more cross-functional MC / VE development at the early stages of the project (as the MC / VE literature states), with the controls group being involved up-front on the key design parameters. The ideal organizational structure may be one that is aligned by product lines rather than by functional expertise. The MC / VE initiatives would then be "owned" by all functions within that Product Line team. This would go a long way in eliminating costly hand-offs from functional group to functional group within the organization.

- The organization should formalize the Value Engineering effort (as outlined in this thesis) in its current MC / VE Work Instructions. This will lead to a more uniform and comprehensive Value Engineering methodology.
- The prevailing culture of the organization (including the commercial and manufacturing groups) needs to change in order to employ the new information technology (like the configurator programs) to define the product. This will reduce the paperwork as well as time to get the relevant hardware and software ordered, thus improving the speed to market.
- The organization should learn to celebrate its successes more, and not just concentrate on what goes wrong with these projects. This is more of a company-wide attitude, where more attention is given to what was unsuccessful in a project, versus what went well.
- For large and complex MC / VE projects, it may be more beneficial to include a "Project engineer" from the organization's Project group, who would be responsible for charting out the task and time schedules (in the form of a Gantt chart / Work Breakdown Structure perhaps). The MC / VE team thus would not get bogged down in project management, and would be free to concentrate on the technical aspects of the project. This would also help management get a handle on the timeframes of

these sub-projects within the projects, without their having to get involved in the day to day aspects of project execution.

- Since the MC / VE efforts generally take a long time, team facilitators as well as management should guard against the loss of interest amongst the team participants over time.

If the researcher were given the opportunity to re-do this research over again, he would probably come up with a different set of variables against which to measure success (perhaps including a "satisfaction index" of some sort, on the outcome of the MC / VE projects). He would also try to include more respondents to the survey so as to make the data more meaningful. Further, he would try to include the commercial / sales / marketing department so as to include their slant on the success of these projects. Perhaps the method of research would be different as well, including more interviewing and focus groups involvement.

This research could serve as additional reading material for MC / VE team members, who are at the beginning stages of starting a MC / VE project. Additionally, this compiles in one place, some key observations related to the MC / VE efforts. Finally, as regards the implications of this study, management should note the themes arrived at in this study, especially about the related activity required to ensure the success of MC / VE projects.

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APPENDICES

APPENDIX 1: SURVEY 1, MEASURES OF SUCCESS IN AN MC / VE PROJECT.

	MEASURES OF SUCCESS IN A MASS CUSTOMIZATION / VALUE ENGINEERING PROJECT				
	Rating:1,2=Low, 3,4=Medium, 5,6=High (ascending order)	"B"	"GG"	"QC"	
1	**$ SAVED (UNIT COST REDUCTION)**				
	Rating: Low = new system costs same or more than older system.				
	Medium = new system costs 1to15% less than older system.				
	High = new system costs 16% or lower than older system.				
2	**REDUCED TIME TO MARKET**				
	(REDUCED MANUFACTURING TIME OR STARTUP TIME OR OVERALL				
	REDUCTION OF PROJECT TIME OR REDUCTION IN AMOUNT OF				
	RECURRING ENGINEERING)				
	Rating: Low = new system takes same or more time than older system.				
	Medium = new system takes 1 to 20% less time than older system.				
	High = new system takes 21% or lower time than older system.				
3	**INCREASED PRODUCT QUALITY WITH REF. TO OLDER DESIGN**				
	(RELATED TO MANUFACTURING DEFECTS, GAPS IN				
	WORK PROCESS, OPERABILITY, RELIABILITY &				
	PERFORMANCE, BETTER DOCUMENTATION, DESIGN)				
	Rating: Low = no different than before / less than 2 categories affected.				
	Medium = improvement in at least 4 categories above.				
	High = improvement in greater than 4 categories above.				
4	**PROJECT COMPLETION WITHIN SPECIFIED TIMEFRAME**				
	Rating: Low = new project exceeded specified time frame.				
	Medium = new project met specified time frame.				
	High = new project took lower than specified time frame.				
5	**PROJECT COMPLETION WITHIN SPECIFIED BUDGET ($)**				
	Rating: Low = new system exceeded specified budget $.				
	Medium = new system met specified budget $.				
	High = new system took less than specified budget $.				
6	**AMOUNT OF RECURRING ENGINEERING PERFORMED (NEW SYSTEMS)**				
	Rating: Low = Recurring eng. on >50% of units sold.				
	Medium = Recurring eng. on 0-49% of units sold.				
	High = No recurring re-engineering required.				

APPENDIX 2: SURVEY 2, PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF AN MC / VE PROJECT.

	PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF A			
	MASS CUSTOMIZATION / VALUE ENGINEERING PROJECT			
	Rating: 1,2=Low, 3,4=Medium, 5,6=High (ascending order)	"B"	"GG"	"QC"
1	**MANAGEMENT COMMITMENT**			
a	TOP-DOWN MANAGEMENT SUPPORT / PUSH			
	Rating: Low = Initial management support only.			
	Medium = intermittent /sporadic management involvement.			
	High = Regular / constant management involvement.			
b	DEPARTMENTAL RESOURCES DEVOTED TO PROJECT			
	Rating: Low = way low, not enough to complete the project workload.			
	Medium = low, just sufficient to complete project workload.			
	High = just right, sufficient to comfortably complete workload.			
c	CONTINUITY OF MEMBERS WITHIN THE PROJECT TEAM (TURNOVER)			
	Rating: Low = constant (>20%) turnover of members within the team.			
	Medium = moderate (1 to 20%) turnover within team.			
	High = No turnover. Original membership intact through end of project.			
d	CLARITY OF PROJECT DEFINITION			
	CLEAR SET OF DELIVERABLES,MISSION/VISION STATEMENT RELEVANCE			
	WHEN DO YOU KNOW WHEN YOU'RE DONE?			
	Rating: Low = vagueness in end product / frequent changes in direction.			
	Medium = project well-defined / hardly any changes mid-stream.			
	High = project deliverables defined in detail / no changes mid-stream.			
2	**PROJECT TEAM LEADERSHIP**			
a	PROJECT LEADER, FACILITATOR (constancy, quality)			
	Rating: Low =leadership change once or more throughout project.			
	Medium = No change in leadership.			
	High = No change in leadership.			
b	DRIVE TO PROJECT COMPLETION (esp. THE LAST 10%)			
	(CONCENTRATE MORE ON THE "DRIVE" ASPECT)			
	Rating: Low = Last X% or higher left incomplete.			
	Medium = completed but not in time.			
	High = completed and within time-frame of project.			
c	CONSENSUS ON TECH. ISSUES WITHIN PROJECT TEAM MEMBERS			
	Rating: Low = Minimal consensus on issues/constant disagreement.			
	Medium = consensus on some issues, but not on others.			
	High = complete consensus on all design issues.			

APPENDIX 2 (continued): SURVEY 2, PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF AN MC / VE PROJECT.

	PARAMETERS CONTRIBUTING TO THE SUCCESS / FAILURE OF A MASS CUSTOMIZATION / VALUE ENGINEERING PROJECT (contd.)			
	Rating: 1,2=Low, 3,4=Medium, 5,6=High (ascending order)	"B"	"GG"	"QC"
3	**MARKET CONDITIONS**			
a	DEGREE OF PRODUCT MATURITY IN MARKET PLACE			
	Rating: Low = new product or less than 1 year in marketplace.			
	Medium = 1 to 3 years in marketplace.			
	High = more than 3 years in marketplace.			
b	ACCURACY OF MARKET INFORMATION (COMMERCIAL INPUT)			
	IDENTIFICATION OF CORRECT OPTIONS			
	Rating: Low = options not/incorrectly defined.			
	Medium = options defined, though not all inclusive.			
	High = options completely defined.			
c	PRODUCT VOLUMES			
	Rating: Low = 1 to 10 per year.			
	Medium = 10 to 30 per year.			
	High = greater than 30 per year.			
4	**SUPPORTING DOCUMENTATION / INFORMATION TECHNOLOGY**			
	POSITION PAPERS, WORK INSTRUCTIONS, CONFIGURATOR, VISIO			
	Rating: Low = positions not documented (<50%), no external IT used.			
	Medium = mostly complete position docs.(>50%), 0-1 external IT used.			
	High = all docs. completed, 1 or more external IT used.			
5	**AMOUNT OF VALUE ENGINEERING PERFORMED**			
	Rating: Low = hardly any older componentry called into question.			
	Medium = about 50% of older design retained.			
	High = brand new design / all parts justified.			
6	**AMOUNT OF MASS CUSTOMIZATION PERFORMED**			
	Rating: Low = still many sub-platforms / hardly any commonality.			
	Medium = moderate combination of sub-platforms / <50% design common.			
	High = 1 sub-platform / more than 50% design common.			
7	**CUSTOMER INFLUENCE (INTERNAL / EXTERNAL)**			
	Rating: Low = no customer input.			
	Medium = occasional customer input.			
	High = fair amount of interaction.			
8	**ADHERANCE TO WORK PROCESS LAID OUT FOR THESE PROJECTS / PROJECT EXECUTION**			
	FOLLOW THE WORK INSTRUCTION WRITTEN FOR ABOVE PROJECTS			
	Rating: Low = not followed / not aware.			
	Medium = followed but not to the letter.			
	High = consistently and clearly followed.			

APPENDIX 3: MC / VE WORK PROCESS AS EMPLOYED IN COMPANY "A".

All MC / VE projects are undertaken utilizing a cross-functional team of around 10 people. The "core team" consists of individuals from the company's engineering, commercial, operations, and safety organizations. A mixture of varied experience levels exists in these teams, which stimulates positive, divergent thinking. A management steering team also provides guidance to the core team on an as-needed basis. The overall program can be broken down into four distinct phases, as shown in Figure 2 below:

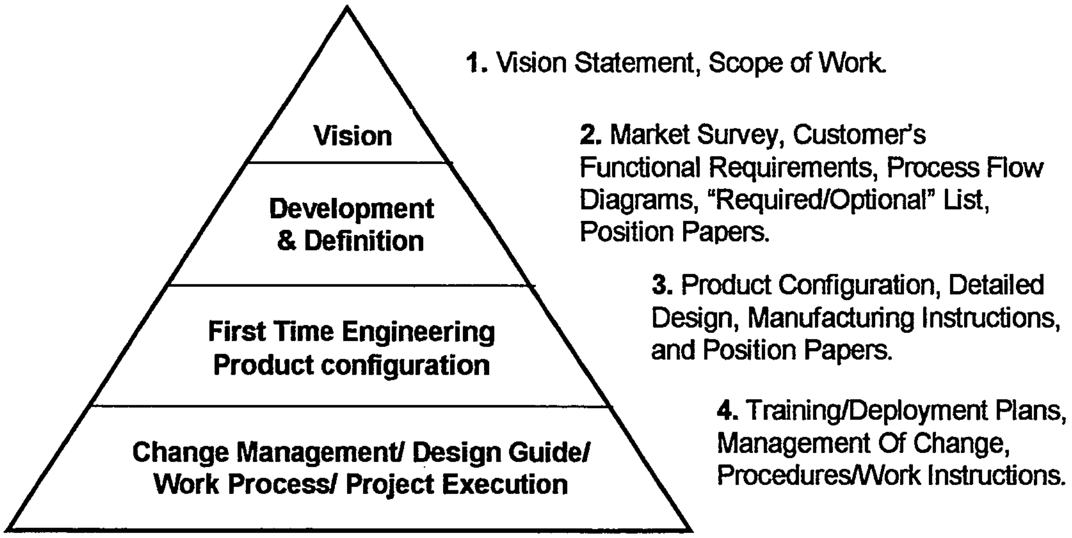


Figure 2: Mass Customization/Value Engineering Essentials.

1. Vision: A clear picture of the future work process is developed at the onset of the program. The vision is communicated to everyone involved along with all the required goals and deliverables of the program. A scope document identifies the required resources, the schedule for critical tasks, and the accountabilities. The scope is also reviewed and approved by the management steering committee.

2. Development and Definition: The core team defines "Building Blocks" in order to subdivide complex systems into manageable pieces (for e.g., process piping and panels, mechanical enclosure, and controller). These blocks are further sub-divided into "Modules". Using Value Engineering, modules are further defined in order to structure the product line into a menu of "Required sub-assemblies" and "Optional sub-assemblies". Required sub-assemblies include the assembly of the most basic components needed to meet customers' basic functional requirements. Optional sub-assemblies include the additional features (above and beyond those required to meet the customers' basic needs) typically ordered by 80% of the customer base. All other options requested infrequently by customers are treated as engineered-to-order (not designed in).

Thus, for the organization, VE is a means of isolating "Required options" for a particular product line. The rest of the system is comprised of "Optional Options".

3. First-Time Engineering: First-time engineering uses various forms of modularity in developing mechanical and electrical designs of the system in its various configurations. These include all possible product line options (required and optional) managed as multiple layers within the drawings.

The knowledge-based product configurator is also developed during this phase. This program produces a database of design rules representing a mass customized and flexible product line. The configurator serves to be an effective order entry tool as well as a design tool, with the ability to provide real-time design deliverables.

4. Change Management: Training and Management of Change (MOC) procedure are the key work processes that maintain the integrity of the product line design. Multiple levels of training programs are developed for engineering, marketing, and sales personnel. Further, a work process has been established that requires all possible design changes to the system to undergo a formal review and approval via the MOC committee.

Thus, Mass Customization, for this organization also includes "Change Management" (proactively).

CULTURAL CHANGES IN THE ORGANIZATION

In order to fully maximize the benefit of MC / VE, the organization has had to shift its focus from being "Project-oriented" to "Product-line oriented". The earlier project focus propagated a "copy exact" approach from one project to another. This lacked the structure to prevent unnecessary custom offerings introduced as minor modifications to the earlier projects. It also had the tendency of propagating ineffective and redundant designs from one project to the next.

The more effective Product-line approach (as shown in Figure 3 below) is based on first routing all product design and improvement ideas through a cross-functional review team. Based on their approval (the review includes technical risk management, feasibility analysis, etc.), the enhancement is added to the product line "master" design. Subsequent projects always return to the "master" as their starting point, rather than beginning from where the last project left off. Incremental enhancements to the product line are recorded and held as part of the product line's detailed design documentation.

Ineffective and outmoded changes rarely survive longer than one project. They are thus not propagated.

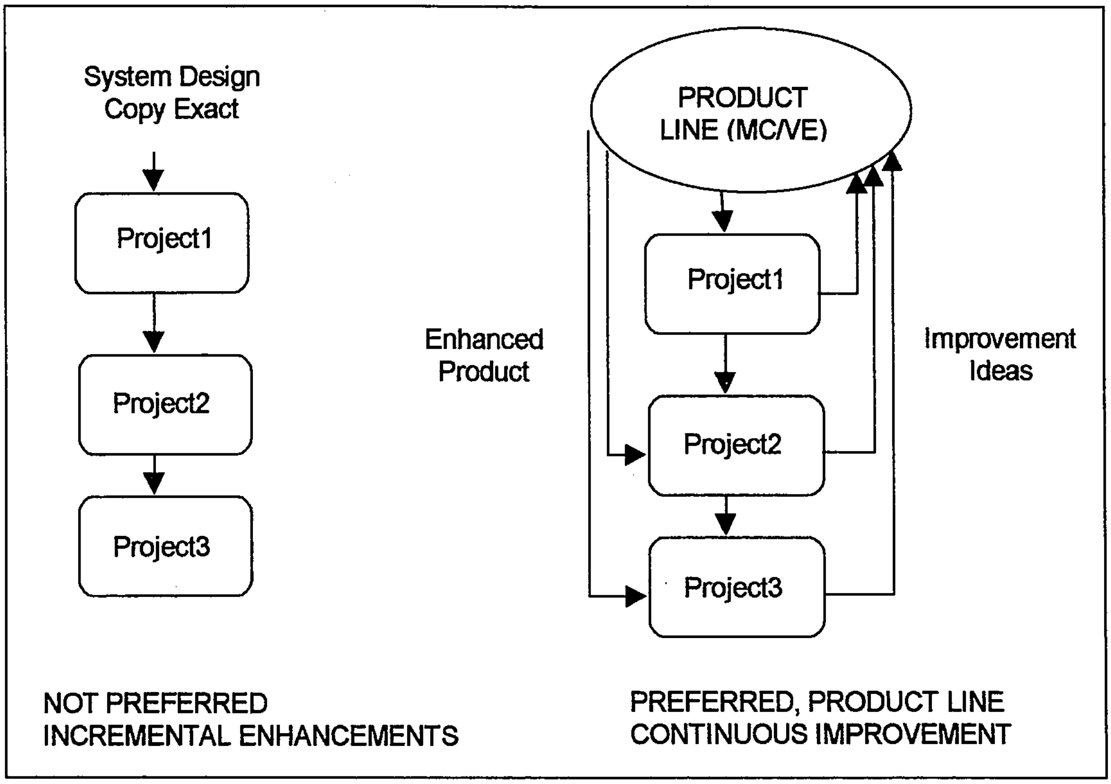
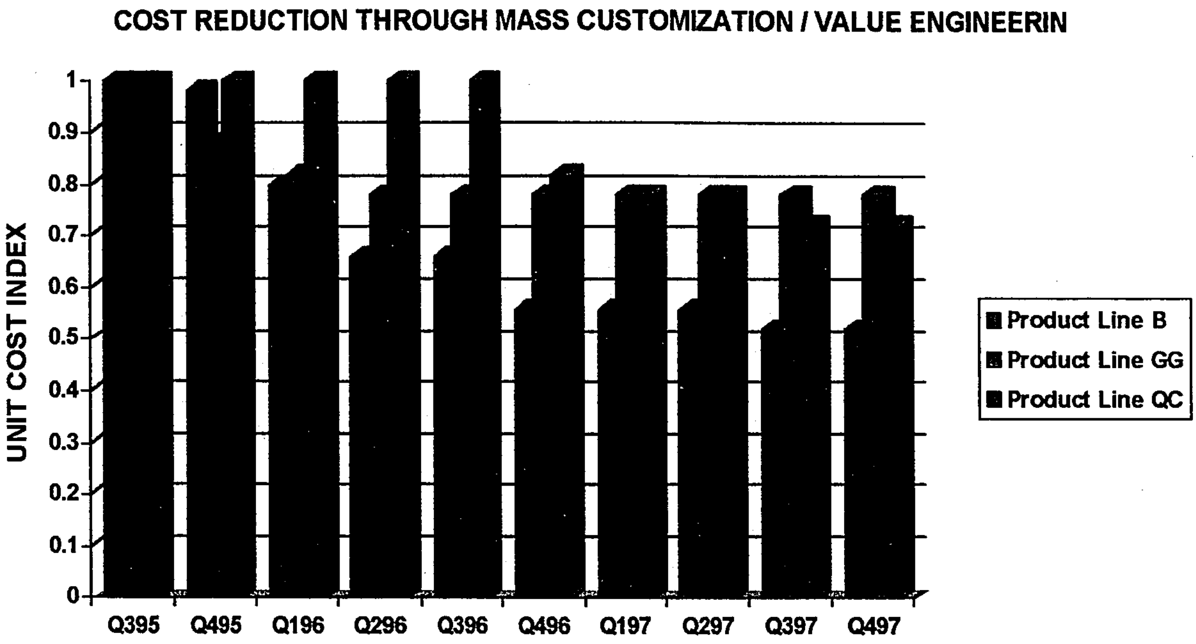


Figure 3: Product Line Approach.

APPENDIX 4: COST REDUCTION DATA FOR PRODUCT LINES B, GG, & QC.



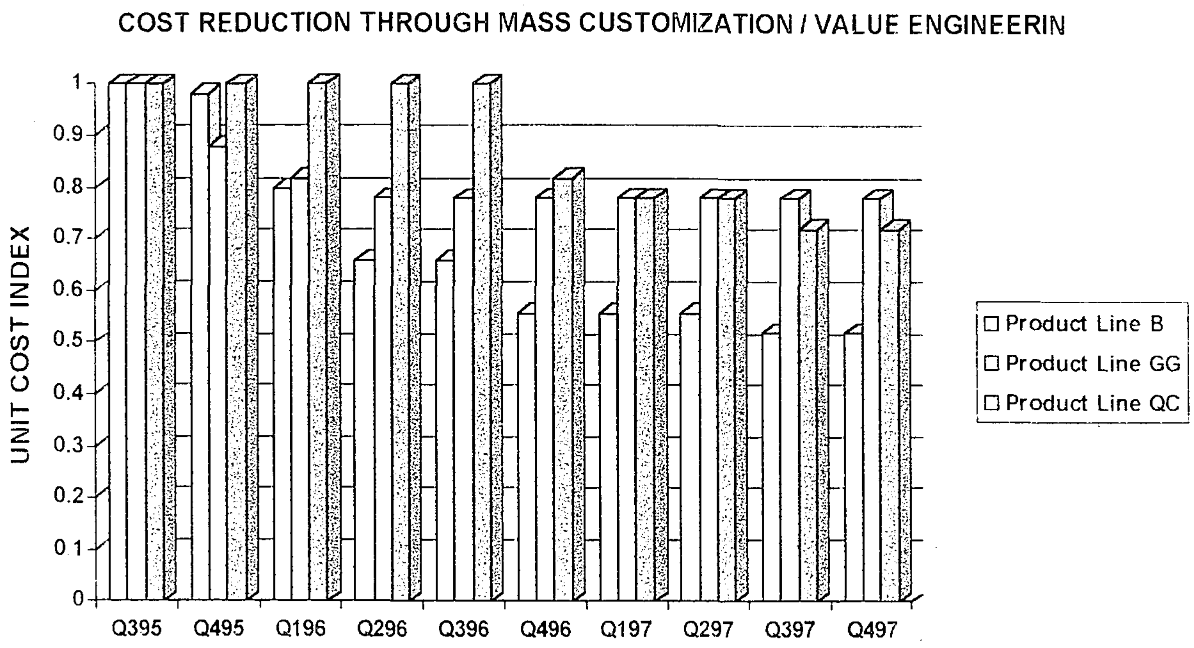
RESULTS OF MC / VE EFFORTS:

Product Line "B" costs lowered by 45%

Product Line "GG" costs lowered by 22%

Product Line "QC" costs lowered by 29%

APPENDIX 4: COST REDUCTION DATA FOR PRODUCT LINES B, GG, & QC.



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Product Line "B" costs lowered by 45%

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VITA

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END

OF

TITLE